CALVAL of the SWOT SSH Spectrum:
Moored GPS Buoy Approach

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June 29, 2017
SWOT 2nd Science Team Meeting
Toulouse FRANCE

GPS Buoy Project

- Joint NASA JPL, NOAA PMEL and U. Washington project funded through NASA ROSES call (Physical Oceanography)*

OBJECTIVES:

- Design, build and test a modular, low-power, robust, high-accuracy GNSS measurement system for long-term, continuous and autonomous operations on ocean- and cryosphere-observing platforms.
- Probe the limits of new kinematic precise-point positioning (PPP) techniques for accurately determining sea-surface height, and recovering neutral and charged atmosphere characteristics.
- Explore potential scientific benefits—in the fields of physical oceanography, weather and space weather—of accurate GNSS observations from a global ocean network of floating platforms.

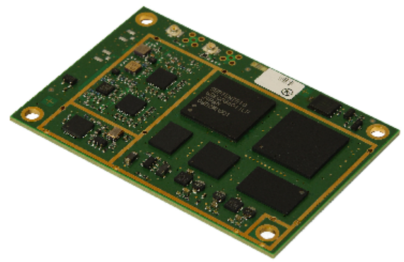
Prototype buoy successfully completed open-ocean testing at Jason crossover location near Daisy Bank off Oregon coast (120 days from May 11–Sept. 8, 2016).

**Extending the Reach of the Global GNSS Network to the World's Oceans: A Prototype Buoy for Monitoring Sea Surface Height, Troposphere and Space Weather*, B. Haines, S. Brown, S. Desai, A. Komjathy, R. Kwok, D. Stowers, C. Meinig and J. Morison.

Prototype Precision GPS Buoy

FEATURES

- Integrated low-power (~1 W), dual-frequency GPS system: Septentrio AsteRX-m credit-card sized receiver + PolarNt-x MF Antenna.
- Miniaturized digital compass/accelerometer.
- Iridium communications (presently used for basic heartbeat information).
- Adaptable to multiple floating platforms (e.g., buoys, wave gliders).
- Delivers geodetic accuracies without nearby reference stations.



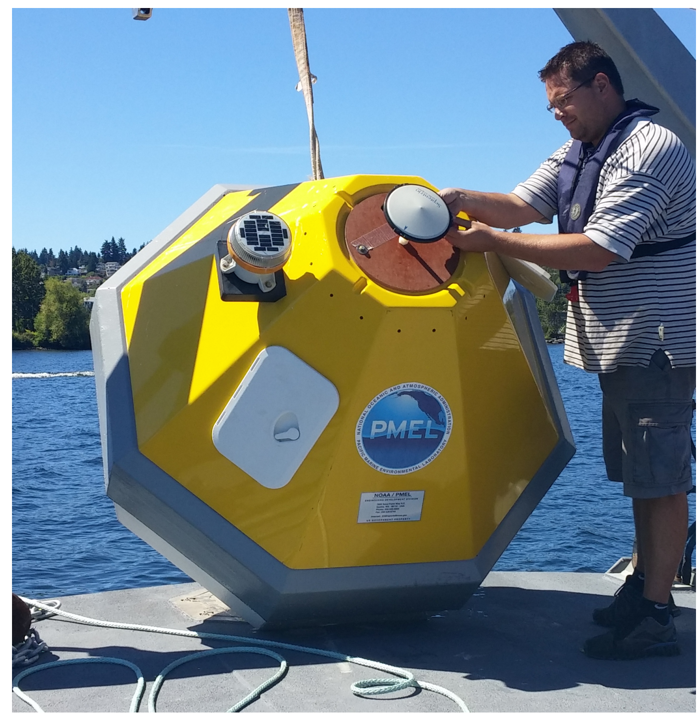
DEVELOPMENT AND TESTING

- Buoy tested successfully under progressively more challenging conditions in US Pacific Northwest:

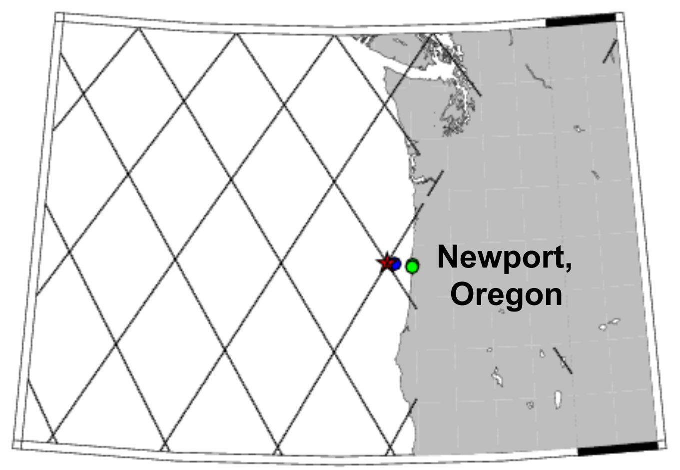
✓ *Lake Washington (Aug. 7–12, 2015).*

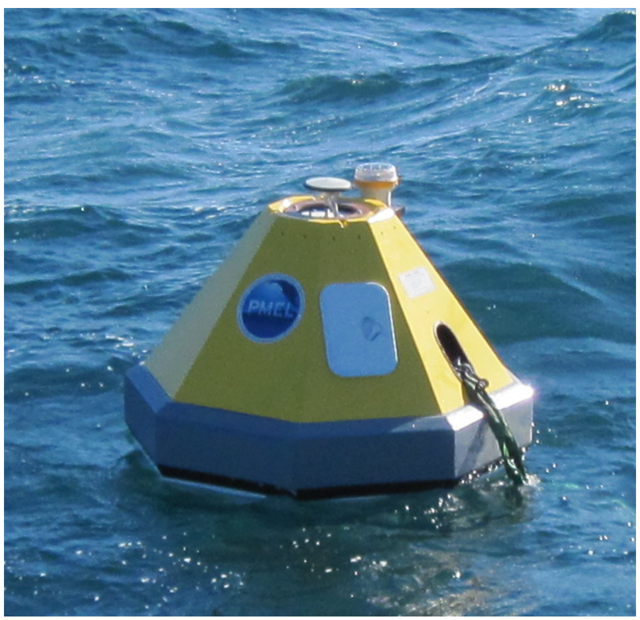
✓ *Puget Sound (Nov. 10 to Dec. 14, 2015).*

✓ *Daisy Bank off Oregon Coast: open ocean Jason crossover location (May 11 to Sep. 8, 2016).*

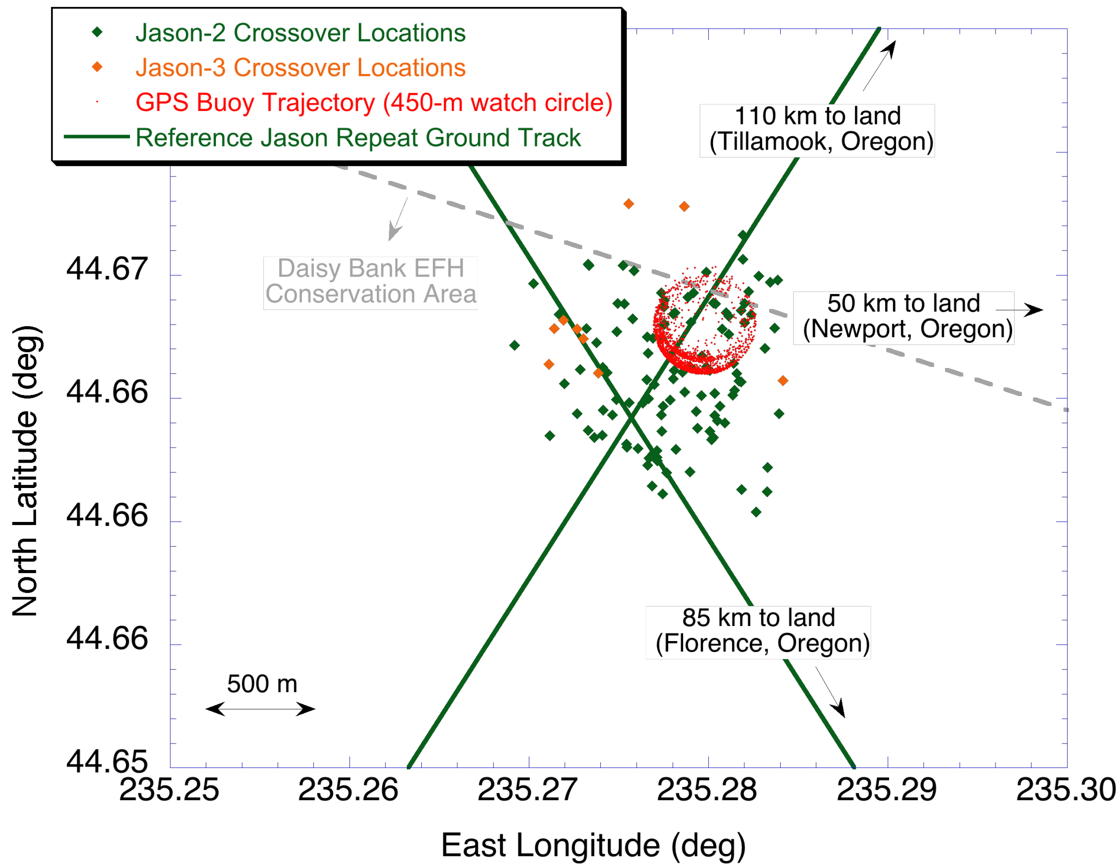


Daisy Bank GPS Buoy





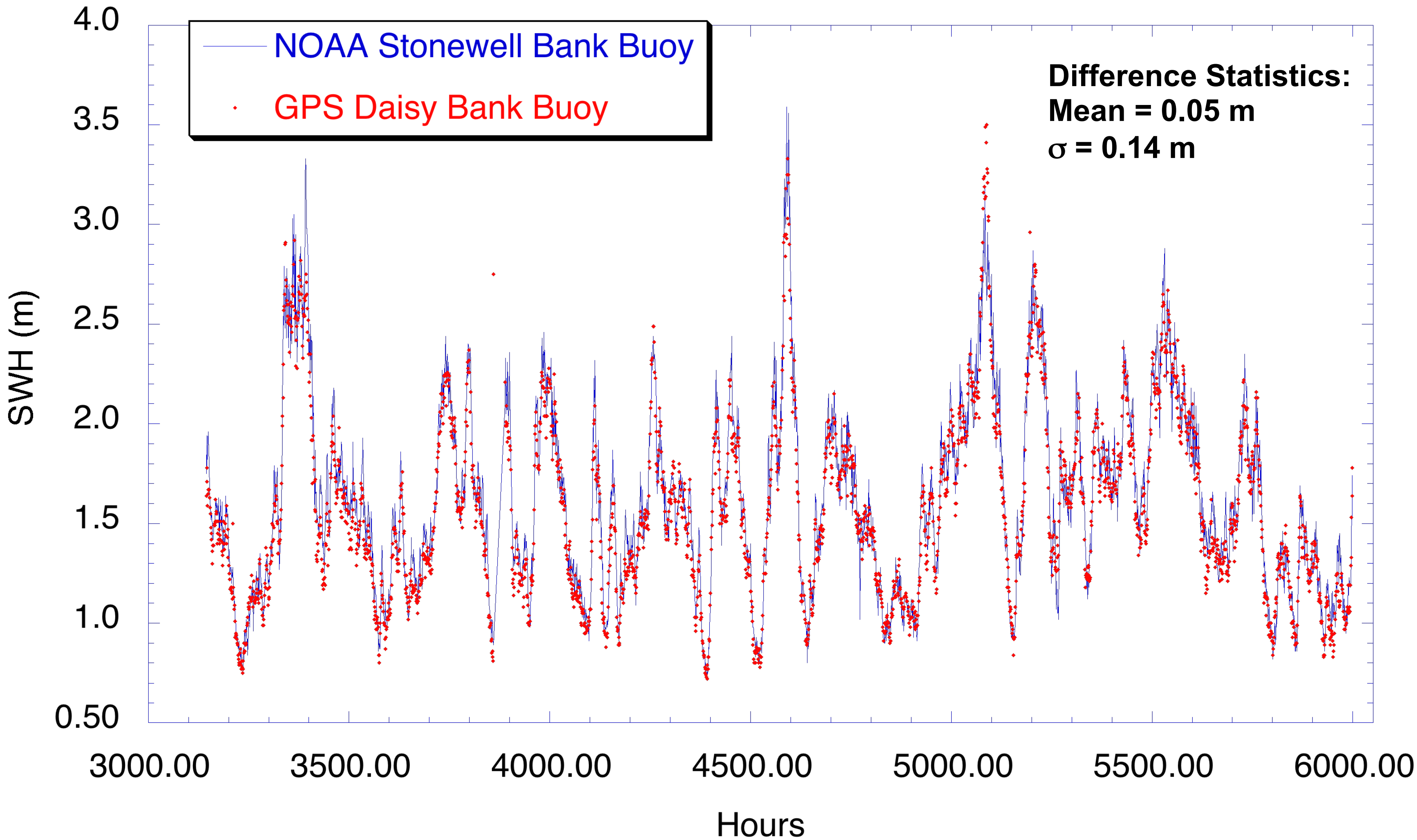
CLOSEUP OF BUOY LOCATION



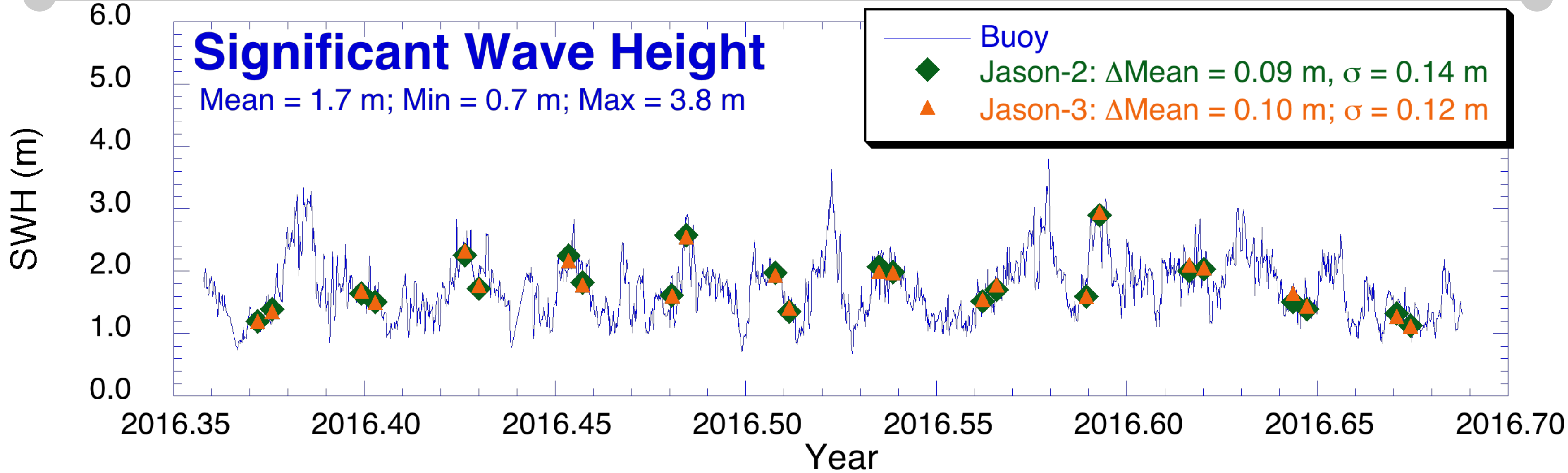
Deployment spanned 24 dual Jason-2/3 overflights

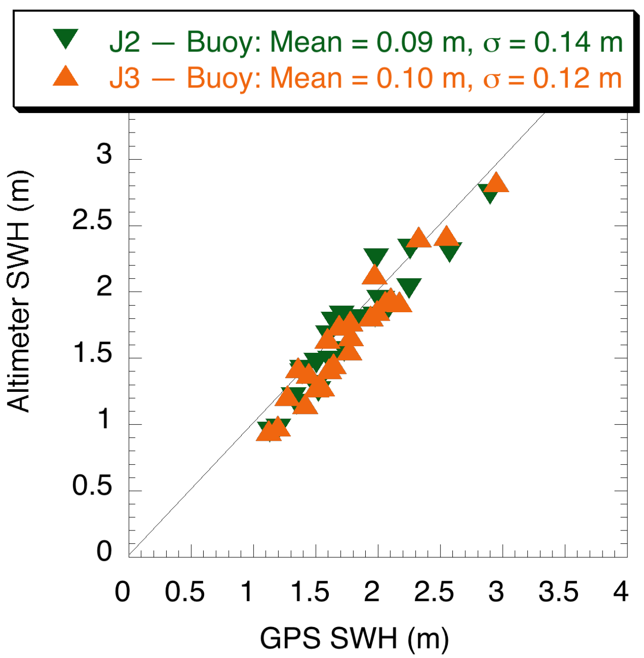
SWH (GPS vs. Traditional NDBC Buoy)

Significant Wave Height Comparisons



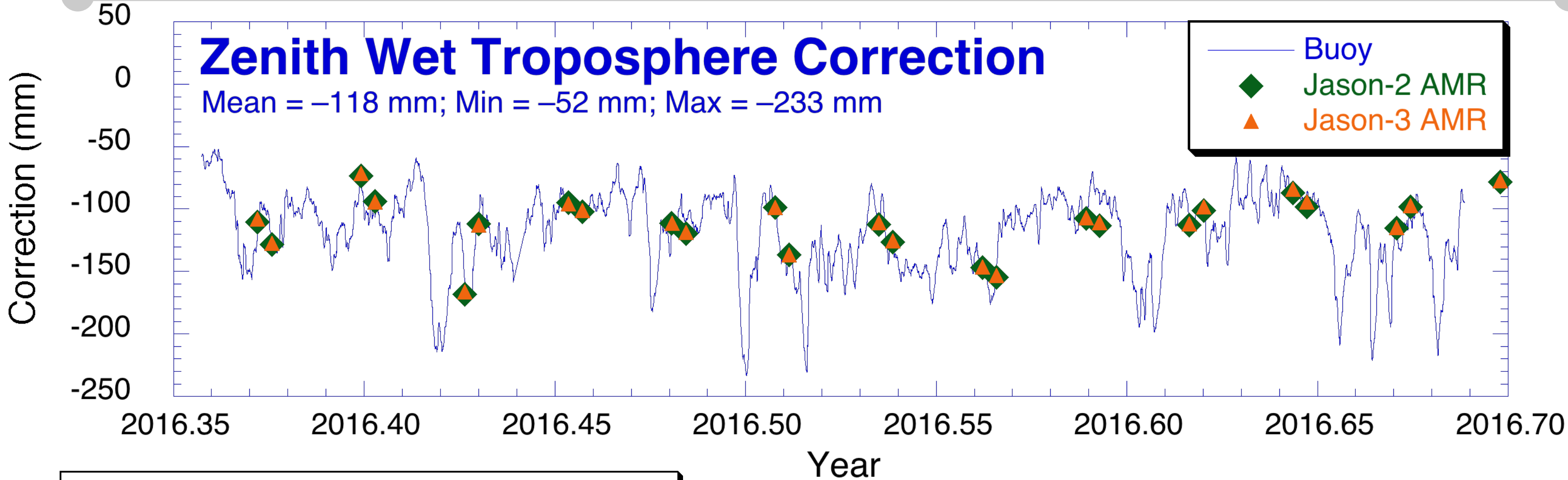
GPS Buoy vs. Altimeter at Daisy Bank: SWH

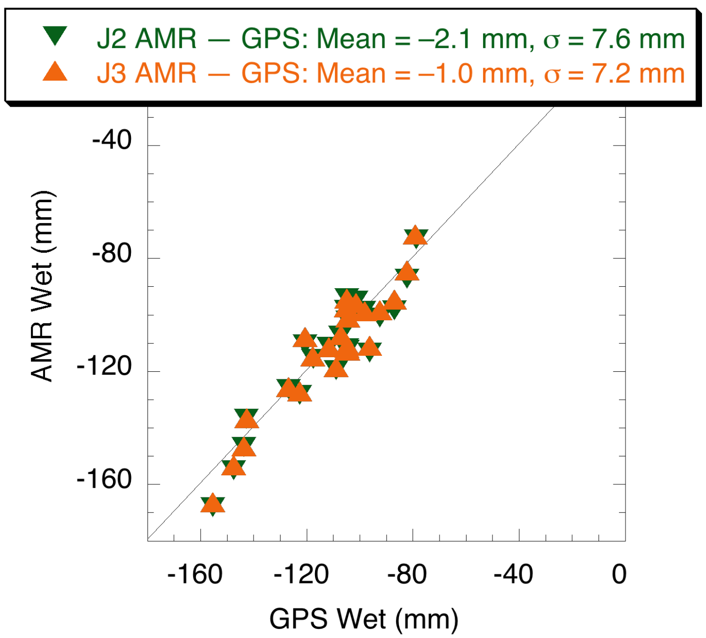




- **Buoy SWH derived from scatter of 1-Hz height estimates over ten minutes.**
  - SWH = 4σ
- **Excellent agreement between buoy and radar altimeter**
  - ~10-cm bias
  - ~10-cm scatter

GPS Buoy vs. Radiometer at Daisy Bank: Wet Troposphere

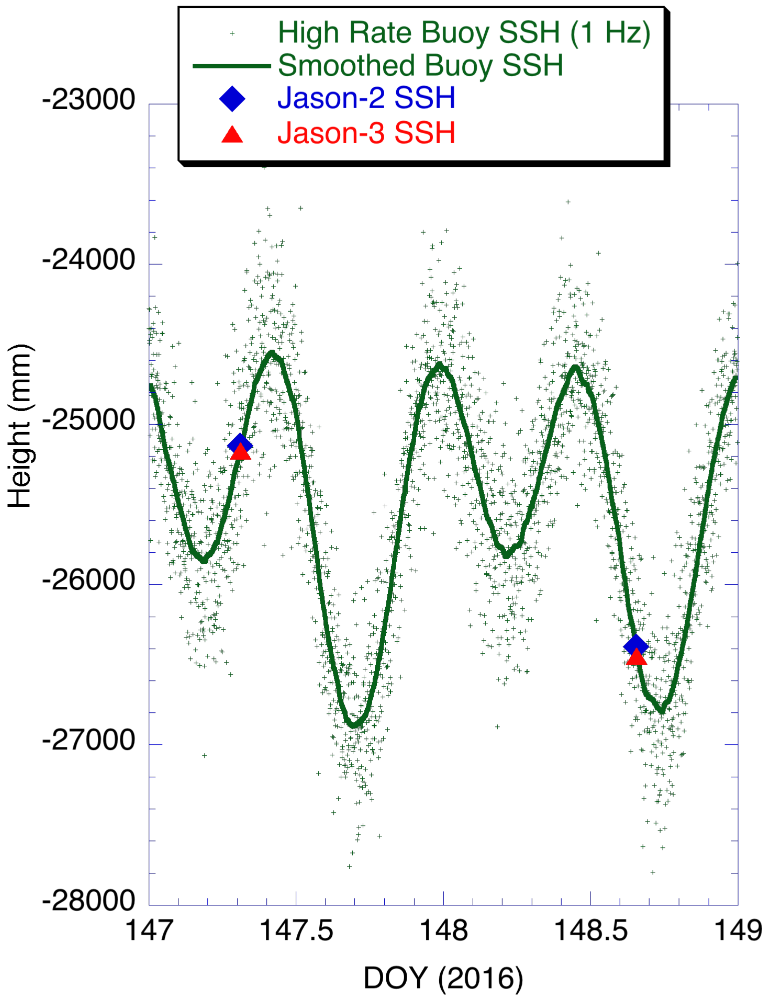


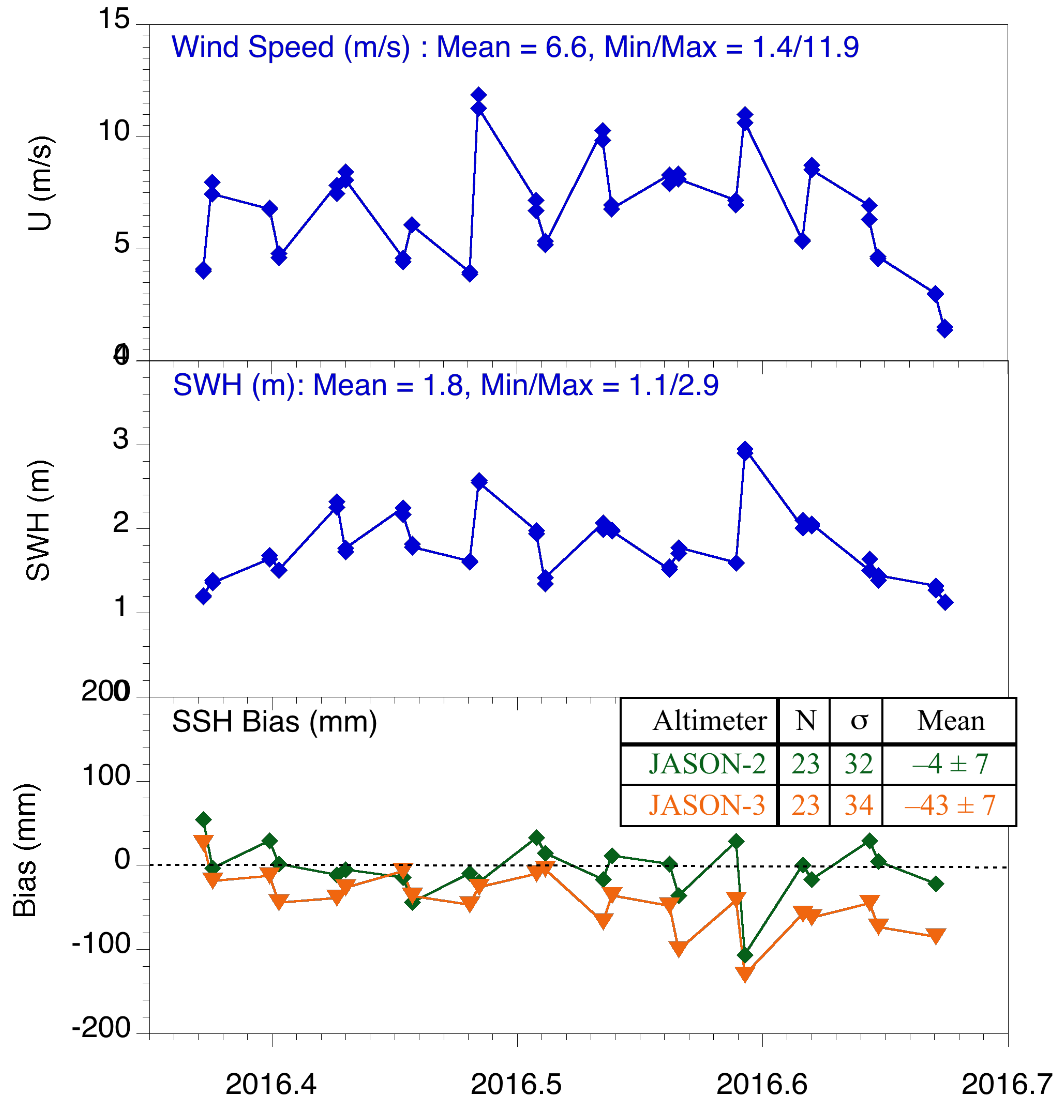


- **Buoy zenith wet troposphere estimated (as random walk) simultaneously with buoy position and clock.**
- **Excellent agreement between buoy and radiometer delay**
  - Bias at mm level
  - Scatter of 7–8 mm

GPS Buoy vs. Altimeter at Daisy Bank: Sea Surface Height

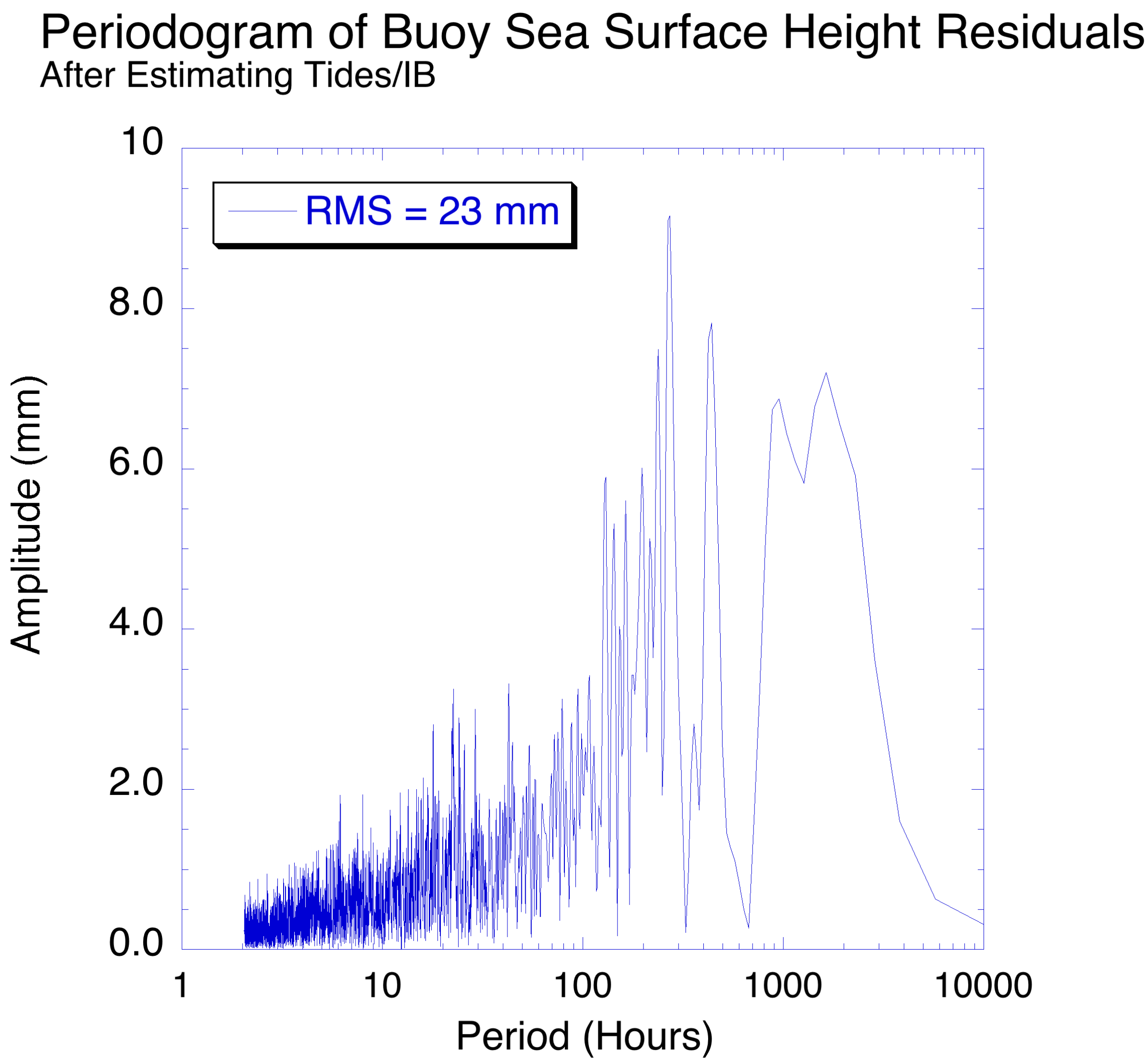
Buoy vs. Altimeter SSH: May 26–27, 2016





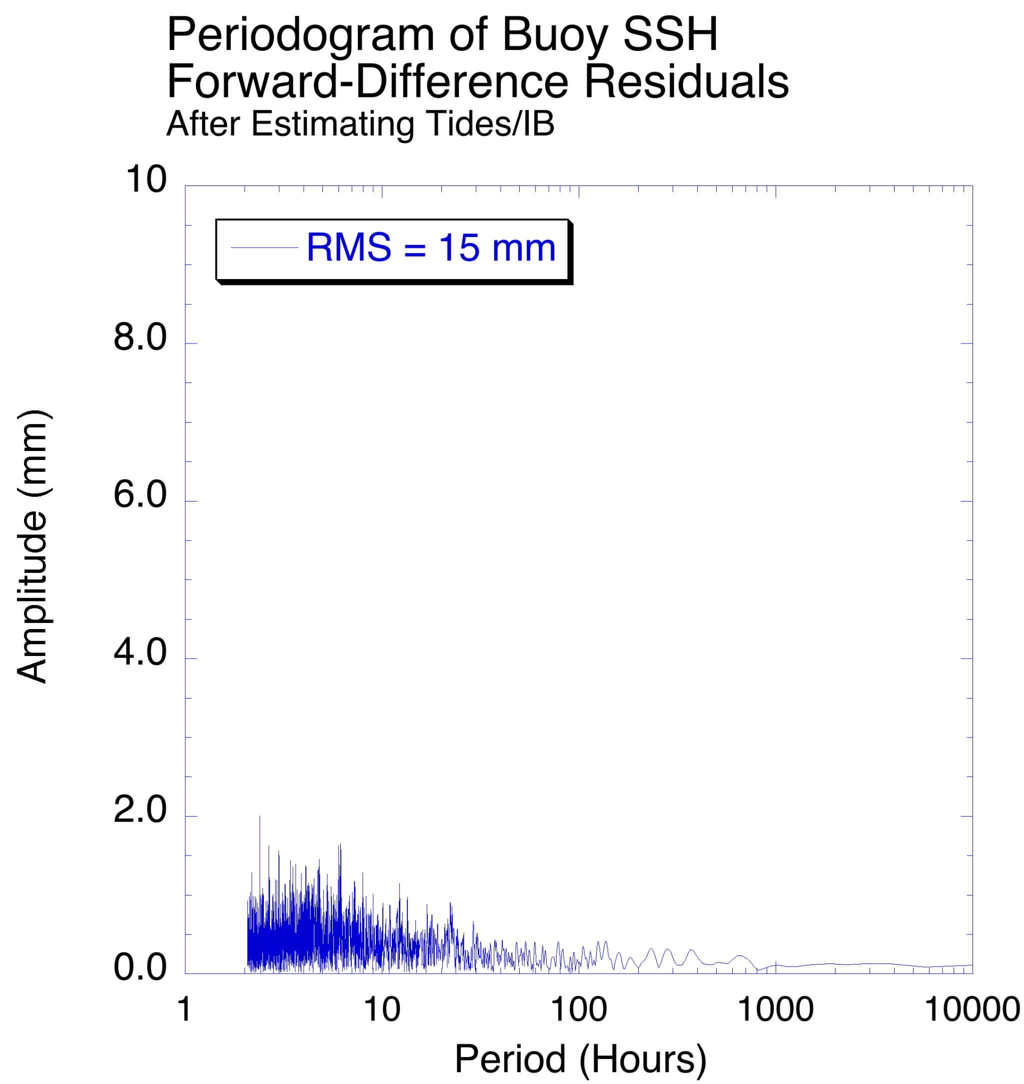
Daisy Bank Buoy SSH Spectra:
ABSOLUTE HEIGHT

- After estimating residual tides and IB, RMS variability of hourly buoy SSH is 2.3 cm.
- Measurements are absolute (geocentric).
- Measurements reflects GPS errors as well true SSH variations (both steric and barotropic).



Daisy Bank Buoy SSH Spectra:
WAVE-INDUCED ERRORS

- Forward differences of hourly SSH are at the 1.5 cm (RMS) level (~1 cm per leg).
- Reflect errors related to both wave sampling and GPS.
- Consistent with the difference of hourly averages from different tapering functions:
  - Boxcar vs. Gaussian: 7 mm
  - Boxcar vs. Cosine: 6 mm



Summary

- **Preliminary results from Daisy Bank GPS buoy very promising**
  - Returned high-quality, uninterrupted data for entire open-ocean test (~120 d).
  - Supported accurate retrievals of SSH, SWH, wet path delay and ionosphere.
  - Competitive with Harvest for all altimeter calibration metrics.
- **Sensitivity of buoy-derived SSH (hourly) to wave effects is at the RMS level of 1 cm or better.**
  - Need short baseline buoy measurements (analogous to SWOT buoy array) to better segregate wave- and GPS-related errors, and to evaluate full potential for SWOT CALVAL.
- **Latest deployment underway: Monterey Bay/SWOT (June – July 2017).**
  - BPR, moorings and subsurface gliders will enable further discrimination of wave-induced errors from GPS measurement errors.